APPENDIX E

LIFE-CYCLE MODEL DESCRIPTION

APPENDIX E. LIFE-CYCLE MODEL DESCRIPTION

1.0 INTRODUCTION

BioSystems developed the life-cycle model to compare the effects of Lower Mokelumne River management alternatives on the number of naturally-produced smolts migrating from the Mokelumne River to the Delta, the total number of smolts migrating out of the Delta past a point near Chipps Island, harvest of these salmon in the ocean fisheries, the number of salmon returning to the Central Valley to spawn, and the number returning to the Mokelumne River. These numbers were used to compare the relative merits of management options for the Mokelumne River.

The model was designed to highlight significant differences between management alternatives and to be as simple as possible. More complex models developed to describe the life-cycle of chinook salmon (i.e., Kimmerer et al. 1989) are useful for exploring specific questions regarding salmon production. The life-cycle model is not meant to precisely mimic the population dynamics of salmon in the Mokelumne River but rather to provide an overview that can be used as an evaluation tool. The model should be used to focus on the major differences between alternatives, not specific numbers.

The predictions of the model are based on assumptions and available information, some of which may be inaccurate. The model represents our understanding of how the system works *given the present state of knowledge*. It is useful for comparing the expected impact of different management objectives, but it is not meant to predict future conditions. The real impact of any management plan will depend on how conditions change in the future, how accurate the model assumptions are, and whether all relevant factors were considered. The real impact can only be determined by monitoring management actions and measuring subsequent fish production.

The model is based on measured characteristics of the Mokelumne River run (i.e., sex-ratio and number of eggs per female) and measured or estimated survival rates at specific points. A general description of the model is provided in Section 2.0 of this appendix, the actual calculation of model output is described in Section 3.0, and the basis for parameter values and rates is documented in Section 4.0. The tables in Section 4.0 provide additional information on model results.

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2.0 GENERAL MODEL DEFINITION

The life-cycle of chinook salmon in the Mokelumne River is depicted in Figure E-1. The two main loops represent natural production in the Mokelumne River and hatchery production at the MRFH.

Salmon populations are adapted to extremely high mortality throughout their life-cycle. Each female salmon in the Mokelumne River produces about 4,600 eggs. If on average, only two progeny per female return to spawn in the river, the population will be maintained. Put another way, the population is adapted to sustain losses as high as 99.96 percent.

Salmon deposit eggs in the gravel of the river bottom, fry hatch and migrate out as fry or they rear to smolt stage, and smolts migrate out through Lake Lodi, the river below Woodbridge, the Delta, and finally into the ocean. In years with high spring flows, fry may out-migrate before becoming smolts, but this has not been modeled. Losses occur at each life stage; the rate of loss varies according to environmental conditions. In dry years, conditions downstream of Lake Lodi are generally so poor that smolts are trapped at Woodbridge Dam and carried below the Delta in trucks. In the ocean, many salmon are harvested in the sport and commercial fisheries. Mature salmon that survive ocean and inland fisheries return to the Mokelumne River to spawn and a small fraction stray to spawn in other rivers. Fish from other river systems also stray into the Mokelumne River.

The hatchery loop of the schematic life cycle (Figure E-1) begins with salmon entering the MRFH. Eggs are taken from these salmon, fertilized, and incubated in the hatchery. Since the number of fish returning to the hatchery is usually insufficient to meet production goals, supplemental eggs (and/or fry) are imported from other hatcheries, especially from the Nimbus Hatchery on the American River and the Feather River Hatchery. Eggs are hatched and the fry are raised to the smolt or yearling stage. Survival is usually much higher in the hatchery than in the natural river environment since the hatchery provides protection from the rigors of the river environment.

In the spring and summer smolts are either released into the Mokelumne River to migrate naturally or they are trucked to or below the Delta to avoid the high mortality associated with migration. Usually, some fish are held through the summer and released as yearlings in the fall. Yearlings have a much higher survival rate than smolts because they are larger and environmental conditions in the fall are less stressful than in the spring. Yearlings usually are released in the Mokelumne River to migrate naturally.

Experiments have shown that more salmon survive to return to the ocean fishery and to inland spawning runs when smolts are released below the Delta than when they are released into the river. However, most of these fish do not return to the Mokelumne River but stray to some other river, usually the American.

Chinook salmon populations in the Mokelumne River can be manipulated in several important ways. The hatchery has a significant effect on the overall productivity of the

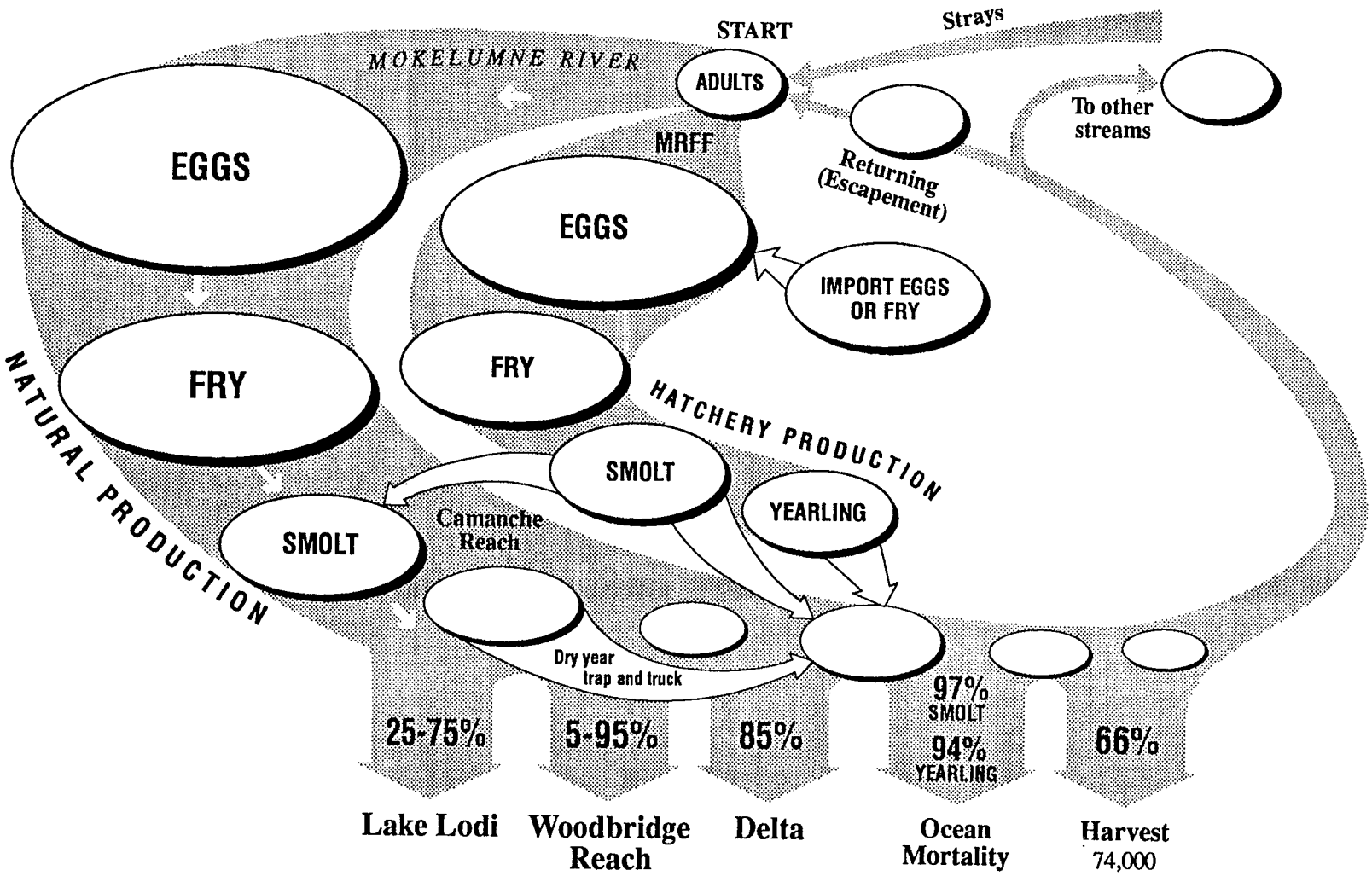

Figure E-1. Life cycle model schematic.

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river, and hatchery practices can significantly effect the number of Mokelumne River salmon harvested in the ocean as well as the numbers of salmon that return to the Mokelumne River. However, salmon that spawn and rear naturally in the river contribute to the overall fitness of the species.

Mortality factors in the life-cycle model were altered to reflect the expected consequences of alternative flow regimes and hatchery management practices. The main variables manipulated were the numbers of smolts and yearlings produced in the hatchery and the location of their release; survival through Lake Lodi; number of smolts trapped and trucked; and survival through the Mokelumne River below Woodbridge Dam. All other parameter values were held constant for each alternative analysis.

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3.0 CALCULATION OF MODEL OUTPUT

The spreadsheet used to calculate salmon population numbers is shown in Table E.1. Each management alternative was defined for either three or four year types, based on annual runoff or a combination of runoff and reservoir storage. The average production across all year types is weighted by the frequency of each year type. The variables used in the model are defined below. Each variation of the model starts with the number of salmon migrating into the Mokelumne to spawn.

Initial Total Number of Spawners

An initial run of 5,000 salmon was used in all cases.

HATCHERY

Number of Spawners Entering Hatchery

An average (1964-1990) of 23 percent of the Mokelumne River run returns to the hatchery.

Eggs from Fish Returning to Hatchery

The number of eggs taken from salmon returning to the Mokelumne River is calculated by multiplying the number of adults returning to the hatchery by the percentage of females and multiplying this figure by the number of eggs per female.

Total Hatchery Eggs Needed

The total number of eggs needed by the hatchery to meet production goals.

Eggs or Fry Imported From Other Hatcheries

Calculated by subtracting the number of Mokelumne River eggs from the total number of hatchery eggs needed.

Number of Smolts Released at MRFH

Entered as input, defined by the management goals of each alternative.

Number of Smolts Released in the Delta

Entered as input, defined by the management goals of each alternative.

Table E.1. Life cycle model calculations

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	16%	34%	36%	14%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	30%	53%	68%	73%
8	OUTMIGRANTS TRAPPED AND TRUCKED	100%	50%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDG	5%	90%	95%	95%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DEL	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRF	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	EXPLANATION
19	INITIAL TOTAL NUMBER OF SPAWNERS	5000	5000	5000	5000	5000	Initial size of spawning run
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHER	1150	1150	1150	1150	1150	Initial total number of spawners x 23%
21	EGGS FROM FISH RETURNING TO HATCHERY	1851500	1851500	1851500	1851500	1851500	number spawning in hatchery x % females x eggs per female
22	TOTAL HATCHERY EGGS NEEDED	5601500	5601500	5601500	5601500	5601500	1.25 x number of smolts and yearlings
23	EGGS OR FRY IMPORTED FROM OTHER HATC	3750000	3750000	3750000	3750000	3750000	total hatchery eggs needed - eggs from fish returning
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	340600	681200	681200	457377	determined by management plan
25	NUMBER OF SMOLTS RELEASED IN DELTA	3681200	3340600	3000000	3000000	3223823	determined by management plan
26	NUMBER OF YEARLINGS RELEASED AT MRFH	800000	800000	800000	800000	800000	determined by management plan
27	NUMBER OF YEARLINGS RELEASED IN DELT	0	0	0	0	0	determined by management plan
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	3850	3850	3850	3850	3850	Initial total number of spawners - number spawning in hatchery
29	EGGS DEPOSITED IN RIVER	6198500	6198500	6198500	6198500	6198500	number spawning naturally x % female x eggs per female
30	FRY HATCHING IN RIVER	1549625	1549625	1549625	1549625	1549625	Row 29 x egg to fry survival
31	NATURAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	Row 30 x fry to smolt survival x outmigrant survival to L. Lodi
32	TOTAL SMOLTS ENTERING LAKE LODI	1006946	1330516	1654086	1654086	1441455	Row 31 + (smolts released at MRFH x outmigrant survival to L. Lodi)
33	SMOLTS SURVIVING LAKE LODI	302084	705174	1124779	1207483	863448	Row 32 x survival through L. Lodi
34	NUMBER OF SMOLTS TRAPPED AND TRUCKE	302084	352587	0	0	168357	Row 33 x % trapped and trucked
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	317328	1068540	1147109	654292	(Row 33 - Row 34) x outmigrant survival from Woodbridge to Delta
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	240157	650487	698317	414416	(Row 33 - Row 34 - surviving hatchery plants) x outmigrant survival from Woodbridge to Delta
37	SMOLTS MIGRATING NATURALLY TO CHIPPS I	0	47599	160281	172066	98144	Row 35 x outmigrant survival through Delta
38	SMOLTS TRUCKED TO CHIPPS ISLAND	3186627	2954549	2400000	2400000	2713744	(Row 34 + Row 25) x survival of smolts released in Delta
39	TOTAL SMOLTS TO CHIPPS ISLAND	3186627	3002149	2560281	2572066	2811888	Row 36 + Row 37
40	YEARLINGS TO CHIPPS ISLAND	360000	360000	360000	360000	360000	Row 26 x survival of yearlings released at MRFH + Row 27 x survival of yearlings released in Delta
41	NUMBER SURVIVING TO BE HARVESTED OR S	117199	111664	98408	98762	105957	Row 38 x ocean survival for smolts + Row 39 x ocean survival for yearlings
42	NUMBER HARVESTED	77351	73699	64950	65183	69931	Row 40 x (1 - percent survivng harvest)
43	TOTAL NUMBER LEFT TO SPAWN	39848	37966	33459	33579	36025	Row 40 x percent surviving harvest
44	NUMBER STRAYING TO OTHER RIVERS	31980	29804	24603	24621	27548	(Row 36 x Row 14 x Row 16 x Row 17) + (Row 37 x Row 14 x Row 16 x Row 18) + (Row 26 x Row 13 x Row 15 x Row 16 x Row 17) + (Row 27 x Row 12 x Row 15 x Row 16 x Row 18)
45	NUMBER RETURNING TO MOKELUMNE	7868	8162	8856	8958	8477	Row 42 - Row 43

Number of Yearlings Released at MRFH

Entered as input, defined by the management goals of each alternative.

Number of Yearlings Released in the Delta

Entered as input, defined by the management goals of each alternative.

RIVER

Number Spawning Naturally in River

The CDFG estimates 77 percent of the run spawns naturally in the river.

Eggs Deposited in River

The number of eggs deposited in the river by wild spawners is calculated by multiplying the number of adults spawning in river by the percentage of females. This figure is then multiplied by the number of eggs per female.

Fry Hatching in River

The number of fry hatching is calculated by multiplying the number of eggs by the egg to fry survival rate.

Natural Smolts Entering Lake Lodi

The number of naturally-produced smolts entering Lake Lodi is calculated by multiplying the number of fry by the fry to smolt survival rate. This figure is then multiplied by the out-migrant survival rate to Lake Lodi.

Total Smolts Entering Lake Lodi

The number of smolts raised in the hatchery and planted in the Mokelumne River is multiplied by the ratio of out-migrant survival to Lake Lodi. This number is added to the number of naturally-produced smolts entering Lake Lodi.

Smolts Surviving Lake Lodi

The number of smolts that survive passage through Lake Lodi is calculated by multiplying the total number of smolts entering Lake Lodi by the rate of mortality through Lake Lodi.

Out-migrants Trapped and Trucked

The number of out-migrants that are trapped and trucked is calculated by multiplying the number of smolts from Lake Lodi by the percentage that are trapped and trucked to the Delta.

Smolts Migrating Naturally to Delta

The number of smolts that migrate naturally to the Delta is calculated by subtracting the number of smolts surviving Lake Lodi from the number of smolts trapped and trucked. This figure is then multiplied by the rate of out-migrant survival from Woodbridge Dam to the Delta.

Smolts Migrating Naturally to Chipps Island

The number of smolts that migrate naturally to Chipps Island is calculated by multiplying the number of smolts migrating naturally to the Delta by the rate of out-migrant survival through the Delta.

Smolts Trucked to Chipps Island

The number of smolts trucked to Chipps Island is calculated by multiplying the number of hatchery smolts trucked to the Delta by the rate of survival of smolts released in the Delta. This figure is then added to the number of smolts trapped and trucked multiplied by the rate of survival of smolts released in the Delta.

Total Number of Smolts Arriving at Chipps Island

This figure is calculated by adding the number of smolts migrating naturally to Chipps Island to the number of smolts trucked to Chipps Island.

Yearlings to Chipps Island

The number of yearlings that reach Chipps Island is calculated by multiplying the number of yearlings released at MRFH by the rate of survival of yearlings released at MRFH. This figure is then added to the number of yearlings released in Delta multiplied by the rate of survival of yearlings released in the Delta.

Number Surviving to be Harvested or Spawn

The number surviving to be harvested or spawned is calculated by multiplying the total number of smolts arriving at Chipps Island by the rate of ocean survival of smolts. This figure is then added to the number of yearlings arriving at Chipps Island multiplied by the rate of ocean survival of yearlings.

Number Harvested

The number harvested is determined by multiplying the number surviving by the harvest rate.

Total Number Left to Spawn

The total number left to spawn is calculated by multiplying the number surviving by the harvest survival rate (includes those that will return to Mokelumne and those that will stray).

Number Straying to Other Rivers

The number of salmon that stray to other rivers is calculated as the number of smolts migrating to Chipps Island multiplied by the ocean survival rate for smolts, the harvest survival rate, and the natural out-migrant straying rate; plus the number of trucked smolts to Chipps Island multiplied by the ocean survival rate for smolts, harvest survival rate, and Delta release straying rate; plus the number of yearlings released at MRFH multiplied by the survival rate of yearlings released at MRFH, the ocean survival rate of yearlings, harvest survival rate, and natural out-migrant straying rate; plus the number of yearlings released in the Delta multiplied by the survival rate of yearlings released in the Delta, ocean survival rate of yearling, harvest survival rate, and Delta release straying rate.

Number Returning to Mokelumne

The number of salmon that return to the Mokelumne River is the total number of fish left to spawn minus the number that stray to other rivers.

4.0 PARAMETER VALUES

Parameter values were based on experimental data from the Mokelumne River, the Delta, and other areas; on estimates; and on values from the scientific literature. Some parameter values are constant in the model and others vary depending on the type of runoff year and flow management scenario. The parameters that vary are in italics below.

Year Frequency

The CDFG Plan and CDFG 1961 base case year type frequency were based on the actual historical period from 1920 to 1990. Wet years have more than 110 percent of the average runoff, and dry years have less than 50 percent of the average runoff. The preferred alternative year type frequency was based on runoff and storage. EBMUD hydrologic models indicated that the frequency would occur as presented.

Females in Run

From 1969-81, 42 percent of the fall-run chinook salmon returning to the Coleman, Nimbus, and Feather River hatcheries were female (CDFG 1967-85; USFWS 1986). The proportion of females varied annually between 10 and 53 percent. The proportion of females in the Mokelumne River run may be somewhat lower than the Sacramento River data indicates. Thirty-five percent of the salmon counted by BioSystems (Appendix A) during the 1990 migration and 47 percent during the 1991 migration were female. Thirty-three percent of the total number of salmon returning and 52 percent of the adults returning to the MRFH between 1964 and 1988 were female (Estey 1990). The life cycle model uses a value of 35 percent females.

Number of Eggs per Female

The average number of eggs per female ranges between 4,600 and 4,800 eggs, based on the relationship between the size and number of eggs of Mokelumne River fish (Jewett and Menchen 1970) and the size data for females passing Woodbridge Dam during the 1990 run (Appendix A). A value of 4,600 eggs per female is used in the life-cycle model.

Egg to Fry Survival

Painter et al. (1977) counted live and dead embryos and fry in Feather River chinook salmon redds. They found that 32 to 99 percent of recovered embryos and fry were alive (average 74%). Their method probably overestimated survival since eggs or fry that die may disintegrate and not be recovered. Shapovalov and Taft (1954) reviewed pertinent literature and concluded that, under favorable conditions (low siltation levels), survival to emergence for coho salmon should be between 65 and 85 percent. Recent investigations in the Mokelumne River indicate survival rates are much lower; however, there may be confounding factors relating to experimental technique (Appendix A). A value of 25 percent was used in the life-cycle model.

Fry to Smolt Survival

BioSystems (Appendix A) trapped and counted out-migrating smolts at Woodbridge Dam in 1989 and 1990. The number of female spawners that produced these smolts was also estimated, as well as the mortality rates of smolts migrating downstream and through Lake Lodi. Using these data, the egg to fry survival rate reported previously, and the measured out-migrant survival rate to Lake Lodi (below), it was calculated that an average of 68 percent of fry survive to smolt stage, and 95 percent of these successfully migrate downstream to Lake Lodi. If the rate of egg to fry survival is different than 25 percent, then the fry to smolt survival rate should be adjusted accordingly.

Out-migrant Survival to Lake Lodi

BioSystems estimated losses of smolts migrating through the Lower Mokelumne River between Camanche Dam and Lake Lodi by releasing known numbers of smolts at Camanche Dam and at Bruella Road (near the upper end of Lake Lodi) and comparing recoveries at Woodbridge Dam. Camanche Dam releases were recovered at only slightly lower frequency (about 2% less) than Bruella Road releases, which indicates that survival between these two points is quite high. Although this difference is probably not significant, a 95 percent survival for out-migrants was assumed in this reach.

Survival Through Lake Lodi

The mortality of smolts travelling through Lake Lodi was measured in 1991 and found to be about 70 percent (Appendix A). Most of the loss appears to occur in the vicinity of the WID fish screen. During the study period, about 89 percent of the total river flow was diverted through the WID Canal. The assumptions for the life-cycle model is that the loss of smolts passing through Lake Lodi is directly related to the percentage of total river flow diverted into the WID Canal and is then equal to 0.79 times the percentage diverted. This loss could change under different flow conditions, but no empirical evidence is available.

WID Canal flow in dry, normal, and wet years was taken from USGS gage records for 1970-1990 (Table E.2). These were compared with out-migration flows below Woodbridge for each flow scenario. The percentage of diversion and associated mortality during the out-migration period also were calculated.

Out-migrants Trapped and Trucked

It is assumed that naturally-produced smolts would be trapped and trucked whenever flow below Woodbridge Dam is insufficient to meet suitable conditions for out-migration. The CDFG Plan specifies (CDFG 1991) that naturally-produced smolts will never be trapped and trucked and stipulates that out-migration flows should be provided during the out-migration period. Under the 1961 CDFG base case, trapping and trucking would be necessary in most years.

Table E.2. WID Canal irrigation diversion by year type and calculation of percentage of diversion and Lake Lodi mortality for different management alternatives

WOODBRIDGE CANAL FLOW (cfs)									FLOW BELOW WOODBRIDGE							
YEAR	YEAR TYPE	MAR	APR	MAY	JUN	JUL	SCENARIO	YEAR TYPE	MAR	APR	MAY	JUN	JUL	WEIGHTED AVERAGE DIVERSION*	MORTALITY	SURVIVAL
1976	Dry	61	116	189	231	202	CDFG	D	200	225	384	20	20	0.58	0.46	0.54
1977	Dry	105	109	76	125	146		N	350	400	506	512	150	0.35	0.27	0.73
1987	Dry	0	124	204	235	233		W	400	450	450	468	300	0.33	0.26	0.74
1988	Dry	46	97	84	166	211										
1989	Dry	0	79	159	212	186	ESCAPEMENT	CD	50	20	20	34	20	0.86	0.68	0.32
1990	Dry	2	91	154	164	200		D	118	125	350	34	20	0.65	0.51	0.49
1991	Dry	0	36	101				N	117	125	350	500	20	0.38	0.30	0.70
1971	Norm	90	229	283	345	382		W	200	125	350	500	20	0.38	0.30	0.70
1972	Norm	88	192	271	322	330										
1975	Norm	11	72	277	312	328	PRODUCTION,	CD	50	20	20	34	20	0.86	0.68	0.32
1979	Norm	0	86	184	239	272	Natural	D	118	125	350	34	20	0.29	0.22	0.78
1981	Norm	1	82	185	245	284		N	117	125	350	500	20	0.41	0.32	0.68
1985	Norm	4	94	200	252	288		W	200	125	350	500	20	0.38	0.30	0.70
1970	Wet	27	256	318	343	364										
1973	Wet	12	162	305	362	367	PRODUCTION,	CD	50	50	50	50	50	0.76	0.60	0.40
1974	Wet	33	58	266	337	347	Hatchery	D	50	50	125	225	50	0.62	0.49	0.51
1978	Wet	3	23	122	220	260		N	50	50	125	225	50	0.59	0.46	0.54
1980	Wet	12	112	161	209	242		W	50	50	125	225	50	0.59	0.46	0.54
1982	Wet	0	12	187	229	268										
1983	Wet	0	16	86	184	235	HARVEST	CD	50	20	20	34	20	0.86	0.68	0.32
1984	Wet	32	163	180	267	310		D	118	20	20	34	20	0.91	0.71	0.29
1986	Wet	0	9	131	210	269		N	117	20	20	20	20	0.92	0.72	0.28
								W	117	20	20	20	20	0.92	0.72	0.28
MEAN	Dry	31	93	138	189	196										
MEAN	Norm	32	126	233	286	314	CDFG BASE CASE	D	42	13	24	31	37	0.86	0.67	0.33
MEAN	Wet	13	90	195	262	296		N	42	13	24	31	37	0.90	0.71	0.29
								W	42	13	24	31	37	0.89	0.70	0.30
							CDFG PLAN	D	55	40	31	38	39	0.82	0.65	0.35
								N	670	407	406	454	270	0.38	0.30	0.70
								W	2421	2083	1801	1301	810	0.14	0.11	0.89

* Monthly values are weighted by the proportion of outmigration occuring in that month: April 1%, May 49%, June 46%, July 4%.
@ Averaged over April and May only

Out-migrant Survival from Woodbridge Dam to the Delta

BioSystems' (Appendix A) studies of smolt out-migration indicate that survival of migrating smolts in the free-flowing section of the river above Lake Lodi is very good. The life-cycle model also assumes good survival below Lake Lodi, as long as temperature conditions are good. Base survival under good conditions in this reach was assumed to be 95 percent. This survival was adjusted downward (through the SCIES score for temperature for each flow scenario, Appendix D) as temperature conditions become less favorable. For example, if the flow scenario resulted in an average SCIES score for out-migration in this reach of 75 percent, then survival was set at 75 percent.

Out-migrant Survival Through the Delta

The USFWS has estimated survival of smolts passing through the Lower Mokelumne River (below the Delta Cross Channel) to Chipps Island (Kjelson et al. 1989). Survival estimates range from 0 to 37 percent and average 15 percent. Survival appeared to be related to water temperature and the amount of diversions from the SWP and CVP pumps. The life-cycle model uses an average value of 15 percent for survival through the Delta. This may be a low estimate of survival for Mokelumne River smolts. Survival of smolts passing through the Delta portions of the Mokelumne River was also estimated by releasing tagged smolts near Thornton in 1984-1986 (USFWS 1988). Survival estimates for smolts released in the south fork of the Mokelumne River range from 23 to 86 percent, while estimates for those released in the north fork range from 28 to 51 percent.

Survival of Smolts Released in the Delta

Some smolts are lost while being trucked and released into the Delta. These losses may be related to handling stress, equipment malfunction, temperature stress, or predation at the release site. These losses are probably highly variable but have not been quantified. The life-cycle model assumes that 80 percent of smolts survive the operation and reach the ocean.

Survival of Yearlings Released in the Delta

The model assumes that yearling survival is somewhat better than that of smolts (lower susceptibility to predation and cooler temperatures at time of release) and uses a value of 90 percent survival.

Survival of Yearlings Released at MRFH

Comparison of releases of yearlings at Rio Vista on the Sacramento River with releases directly at the MRFH indicate that about twice as many of the Delta releases are recovered in the ocean fisheries. The life-cycle model matches these data by assuming that survival of river-released smolts to Chipps Island is half of that for Delta releases (or 45%) and is equivalent for both release groups from that point on.

Ocean Survival of Smolts

This is an estimate of the proportion of smolts that survive to be caught in the ocean fishery or return to spawn in rivers of the Central Valley. Estimates of smolt production, ocean harvest, and spawning escapement for Central Valley fall-run salmon are described in Kimmerer et al. (1989) for a salmon population model for the Sacramento Basin (CPOP-2). This analysis indicates that about 3 percent of smolts migrating out of the San Francisco Estuary survive to be caught in the ocean fishery or return to spawn. Kelley et al. (1991) have derived a similar estimate.

Ocean Survival of Yearlings

Salmon released as yearlings should have higher survival rates than those released as smolts, because of larger size at out-migration (Reisenbichler et al. 1982) and later attainment of harvestable size (Hankin 1987; Cramer 1989 Draft). Studies by CDFG with Feather River fish released in the Delta indicated that salmon released as yearlings contribute 5.1 times more to the ocean fishery and 17.5 times more to spawning stocks than those released as fingerlings (weight = 5 grams or about smolt size) (Sholes and Hallock 1979). Yearling-released fish may not become available to the fishery until their third year and, therefore, are subjected to lower harvest rates. This may be compensated for by greater harvest rates in their fourth year. The difference in harvest rates may not necessarily reflect a similar difference in survival rate. The life-cycle model assumes that ocean survival for yearlings is twice as great as for smolts, or about 6 percent.

Harvest Survival

The Pacific Fisheries Management Council (PFMC) provides annual indices of abundance and ocean fishery impacts on California Central Valley chinook salmon. Between 1970 and 1990 ocean chinook landings south of Point Arena have averaged 66 percent of the abundance index (landings plus Central Valley Escapement) (Table E.3). Survival was therefore 34 percent.

Natural Out-migrant Straying Rate

Straying rates are estimated from recoveries of marked salmon released at different locations and at different times. Salmon are marked with coded wire tags (CWT) inserted in their snout and an externally visible mark such as removal of the adipose fin. Recoveries of fish marked with CWTs and released at the MRFH indicate that 85 percent of fish migrating naturally out of the Mokelumne return to the Mokelumne, while the other 15 percent return to other rivers, mostly the American and Feather.

Delta Release Straying Rate

Recoveries of fish marked with CWTs and released in the Delta show that about 95 percent of these fish return to rivers other than the Mokelumne.

Table E.3. Indices of annual abundance and ocean fishery impacts on California Central Valley chinook salmon, 1970-1990, in thousands of fish. Data from Pacific Fishery Management Council (1991).

YEAR	OCEAN CHINOOK LANDINGS			HATCHERY AND NATURAL ESCAPEMENTS OF CENTRAL VALLEY ADULTS			ABUNDANCE INDEX OCEAN + RIVER TOTALS)	OCEAN HARVEST RATE INDEX (PERCENT)[2]
	TROLL	SPORT	TOTAL	FALL	OTHER[1]	TOTAL		
1970	226.8	111.1	337.9	190.5	55.6[3]	246.0	584.0	58
1971	150.7	166.3	317.0	190.6	62.0	252.6	569.6	56
1972	229.8	187.6	417.4	99.6	46.1	145.7	563.1	74
1973	422.5	180.9	603.4	227.1	27.1	254.2	857.6	70
1974	282.7	141.6	424.3	205.6	35.7	241.3	665.6	64
1975	234.4	92.7	327.1	159.2	47.6	206.8	533.9	61
1976	237.8	68.6	306.4	168.8	43.8	212.6	519.0	59
1977	263.9	76.6	340.4	155.7	42.8	198.5	538.9	63
1978	291.0	65.3	356.3	136.9	17.1	154.0	510.3	70
1979	234.2	108.4	342.6	167.9	11.3	179.2	521.7	66
1980	294.3	76.2	370.5	155.9	31.6	187.5	558.0	66
1981	289.9	75.4	362.3	187.4	18.7	206.1	568.4	64
1982	418.4	123.9	542.3	173.7	36.8	210.5	752.8	72
1983	178.2	59.9	238.1	121.5	14.2	135.7	373.8	64
1984	221.7	80.6	302.3	204.2	17.6	221.8	524.1	58
1985	206.0	121.7	327.7	304.6	19.0	323.7	651.4	50
1986	502.5	114.8	617.3	256.4	30.3	286.7	904.0	68
1987	446.8	152.8	599.7	185.5	25.2	210.7	810.4	74
1988	830.5	131.3	961.8	235.4	23.3	258.7	1,220.4	79
1989	363.7	130.9	494.6	155.0	16.4	171.4	666.0	74
1990	329.9	90.2	420.2	121.1	12.9[4]	134.0	554.2	76
AVERAGE								66

[1]Spring run of the current calendar year and late-fall and winter runs of the following calendar year.
[2]Ocean harvest landed south of Pt. Arena as a percent of the abundance index.
[3]Percent of adults in 1970 spring run assumed the same as 1971 (72%, 5,500 total).
[4]Winter run assumed to be the same as previous year.

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5.0 RESULTS

Table E.4 gives results for each management alternative. Table E.5 summarizes the fishery benefits of management alternatives.

Table E.4. Life cycle model output.

CDFG ALTERNATIVE

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	0%	14%	47%	39%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	0%	54%	73%	74%
8	OUTMIGRANTS TRAPPED AND TRUCKED	0%	0%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	0%	48%	84%	83%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	EXPLANATION
19	INITIAL TOTAL NUMBER OF SPAWNERS	0	5000	5000	5000	5000	Initial size of spawning run
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	0	1150	1150	1150	1150	Initial total number of spawners x 23%
21	EGGS FROM FISH RETURNING TO HATCHERY	0	1851500	1851500	1851500	1851500	number spawning in hatchery x % females x eggs per female
22	TOTAL HATCHERY EGGS NEEDED	0	5833333	5833333	5833333	5833333	1.25 x number of smolts and yearlings
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	0	3981833	3981833	3981833	3981833	total hatchery eggs needed - eggs from fish returning
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	0	0	0	0	determined by management plan
25	NUMBER OF SMOLTS RELEASED IN DELTA	0	2000000	2000000	2000000	2000000	determined by management plan
26	NUMBER OF YEARLINGS RELEASED AT MRFH	0	1500000	1500000	1500000	1500000	determined by management plan
27	NUMBER OF YEARLINGS RELEASED IN DELTA	0	0	0	0	0	determined by management plan
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	0	3850	3850	3850	3850	Initial total number of spawners - number spawning in hatchery
29	EGGS DEPOSITED IN RIVER	0	6198500	6198500	6198500	6198500	number spawning naturally x % female x eggs per female
30	FRY HATCHING IN RIVER	0	1549625	1549625	1549625	1549625	Row 29 x egg to fry survival
31	NATURAL SMOLTS ENTERING LAKE LODI	0	1006946	1006946	1006946	1006946	Row 30 x fry to smolt survival x outmigrant survival to L. Lodi
32	TOTAL SMOLTS ENTERING LAKE LODI	0	1006946	1006946	1006946	1006946	Row 31 + (smolts released at MRFH x outmigrant survival to L. Lodi)
33	SMOLTS SURVIVING LAKE LODI	0	543751	735071	745140	712213	Row 32 x survival through L. Lodi
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	0	0	0	0	0	Row 33 x % trapped and trucked
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	261000	617459	618466	567948	(Row 33 - Row 34) x outmigrant survival from Woodbridge to Delta
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	261000	617459	618466	567948	(Row 33 - Row 34 - surviving hatchery plants) x outmigrant survival from Woodbridge to Delta
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	39150	92619	92770	85192	Row 35 x outmigrant survival through Delta
38	SMOLTS TRUCKED TO CHIPPS ISLAND	0	1600000	1600000	1600000	1600000	(Row 34 + Row 25) x survival of smolts released in Delta
39	TOTAL SMOLTS TO CHIPPS ISLAND	0	1639150	1692619	1692770	1685192	Row 36 + Row 37
40	YEARLINGS TO CHIPPS ISLAND	0	675000	675000	675000	675000	Row 26 x survival of yearlings released at MRFH + Row 27 x survival of yearlings released in Delta
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	0	89675	91279	91283	91056	Row 38 x ocean survival for smolts + Row 39 x ocean survival for yearlings
42	NUMBER HARVESTED	0	59185	60244	60247	60097	Row 40 x (1 - percent surviving harvest)
43	TOTAL NUMBER LEFT TO SPAWN	0	30489	31035	31036	30959	Row 40 x percent surviving harvest
44	NUMBER STRAYING TO OTHER RIVERS	0	17629	17711	17711	17700	(Row 36 x Row 14 x Row 16 x Row 17)+(Row 37 x Row 14 x Row 16 x Row 18)+ (Row 26 x Row 13 x Row 15 x Row 16 x Row 17) + (Row 27 x Row 12 x Row 15 x Row 16 x Row 18)
45	NUMBER RETURNING TO MOKELUMNE	0	12860	13324	13325	13259	Row 42 - Row 43

Table E.4. Life cycle model output (cont.).

ESCAPEMENT ORIENTED ALTERNATIVE

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	20%	27%	11%	41%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	32%	49%	70%	70%
8	OUTMIGRANTS TRAPPED AND TRUCKED	100%	50%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	20%	45%	83%	83%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	0.15	0.15	0.15	0.15
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	0.8	0.8	0.8	0.8
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	0.9	0.9	0.9	0.9
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	0.45	0.45	0.45	0.45
14	OCEAN SURVIVAL OF SMOLTS	0.03	0.03	0.03	0.03
15	OCEAN SURVIVAL OF YEARLINGS	0.06	0.06	0.06	0.06
16	SURVIVING HARVEST	0.34	0.34	0.34	0.34
17	NATURAL OUTMIGRANT STRAYING RATE	0.15	0.15	0.15	0.15
18	DELTA RELEASE STRAYING RATE	0.95	0.95	0.95	0.95

	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	EXPLANATION
19	INITIAL TOTAL NUMBER OF SPAWNERS	5000	5000	5000	5000	5000	Initial size of spawning run
20	NUMBER OF SPAWNERS ENTERING HATCHERY	1150	1150	1150	1150	1150	Initial total number of spawners x 23%
21	EGGS FROM FISH RETURNING TO HATCHERY	1851500	1851500	1851500	1851500	1851500	number spawning in hatchery x % females x eggs per female
22	TOTAL HATCHERY EGGS NEEDED	3166667	3166667	3166667	3166667	3166667	1.25 x number of smolts and yearlings
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	1315167	1315167	1315167	1315167	1315167	total hatchery eggs needed - eggs from fish returning
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	0	0	0	0	determined by management plan
25	NUMBER OF SMOLTS RELEASED IN DELTA	1370000	1370000	1370000	1370000	1370000	determined by management plan
26	NUMBER OF YEARLINGS RELEASED AT MRFH	0	0	0	0	0	determined by management plan
27	NUMBER OF YEARLINGS RELEASED IN DELTA	530000	530000	530000	530000	530000	determined by management plan
28	NUMBER SPAWNING NATURALLY IN RIVER	3850	3850	3850	3850	3850	Initial total number of spawners - number spawning in hatchery
29	EGGS DEPOSITED IN RIVER	6198500	6198500	6198500	6198500	6198500	number spawning naturally x % female x eggs per female
30	FRY HATCHING IN RIVER	1549625	1549625	1549625	1549625	1549625	Row 29 x egg to fry survival
31	NATURAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	Row 30 x fry to smolt survival x outmigrant survival to L. Lodi
32	TOTAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	Row 31 + (smolts released at MRFH x outmigrant survival to L. Lodi)
33	SMOLTS SURVIVING LAKE LODI	322223	493404	704862	704862	570939	Row 32 x survival through L. Lodi
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	322223	246702	0	0	131406	Row 33 x % trapped and trucked
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	111016	585036	585036	339366	(Row 33 - Row 34) x outmigrant survival from Woodbridge to Delta
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	111016	585036	585036	339366	(Row 33 - Row 34 - surviving hatchery plants) x outmigrant survival from Woodbridge to Delta
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	16652	87755	87755	50905	Row 35 x outmigrant survival through Delta
38	SMOLTS TRUCKED TO CHIPPS ISLAND	1353778	1293361	1096000	1096000	1201125	(Row 34 + Row 25) x survival of smolts released in Delta
39	TOTAL SMOLTS TO CHIPPS ISLAND	1353778	1310014	1183755	1183755	1252030	Row 36 + Row 37
40	YEARLINGS TO CHIPPS ISLAND	477000	477000	477000	477000	477000	Row 26 x survival of yearlings released at MRFH + Row 27 x survival of yearlings released in Delta
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	69233	67920	64133	64133	66181	Row 38 x ocean survival for smolts + Row 39 x ocean survival for yearlings
42	NUMBER HARVESTED	45694	44827	42328	42328	43679	Row 40 x (1 - percent surviving harvest)
43	TOTAL NUMBER LEFT TO SPAWN	23539	23093	21805	21805	22502	Row 40 x percent surviving harvest
44	NUMBER STRAYING TO OTHER RIVERS	22362	21802	19999	19999	20961	(Row 36 x Row 14 x Row 16 x Row 17)+(Row 37 x Row 14 x Row 16 x Row 18)+ (Row 26 x Row 13 x Row 15 x Row 16 x Row 17) + (Row 27 x Row 12 x Row 15 x Row 16 x Row 18)
45	NUMBER RETURNING TO MOKELUMNE	1177	1291	1806	1806	1540	Row 42 - Row 43

Table E.4. Life cycle model output (cont.).

PRODUCTION ORIENTED ALTERNATIVE, NATURAL EMPHASIS

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	16%	34%	36%	14%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	32%	78%	68%	70%
8	OUTMIGRANTS TRAPPED AND TRUCKED	100%	50%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	20%	90%	83%	83%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	EXPLANATION
19	INITIAL TOTAL NUMBER OF SPAWNERS	5000	5000	5000	5000	5000	Initial size of spawning run
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	1150	1150	1150	1150	1150	Initial total number of spawners x 23%
21	EGGS FROM FISH RETURNING TO HATCHERY	1851500	1851500	1851500	1851500	1851500	number spawning in hatchery x % females x eggs per female
22	TOTAL HATCHERY EGGS NEEDED	7184833	7184833	7184833	7184833	7184833	1.25 x number of smolts and yearlings
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	5333333	5333333	5333333	5333333	5333333	total hatchery eggs needed - eggs from fish returning
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	155450	310900	310900	208303	determined by management plan
25	NUMBER OF SMOLTS RELEASED IN DELTA	3510900	3355450	3200000	3200000	3302597	determined by management plan
26	NUMBER OF YEARLINGS RELEASED AT MRFH	800000	800000	800000	800000	800000	determined by management plan
27	NUMBER OF YEARLINGS RELEASED IN DELTA	0	0	0	0	0	determined by management plan
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	3850	3850	3850	3850	3850	Initial total number of spawners - number spawning in hatchery
29	EGGS DEPOSITED IN RIVER	6198500	6198500	6198500	6198500	6198500	number spawning naturally x % female x eggs per female
30	FRY HATCHING IN RIVER	1549625	1549625	1549625	1549625	1549625	Row 29 x egg to fry survival
31	NATURAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	Row 30 x fry to smolt survival x outmigrant survival to L. Lodi
32	TOTAL SMOLTS ENTERING LAKE LODI	0	658923	1317846	1317846	882957	Row 32 x survival through L. Lodi
33	SMOLTS SURVIVING LAKE LODI	0	513960	896136	922492	626504	Row 31 + (smolts released at MRFH x outmigrant survival to L. Lodi)
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	1006946	503473	0	0	332292	Row 33 x % trapped and trucked
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	462564	743792	765669	532231	(Row 33 - Row 34) x outmigrant survival from Woodbridge to Delta
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	410729	577094	594067	430571	(Row 33 - Row 34 - surviving hatchery plants) x outmigrant survival from Woodbridge to Delta
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	69385	111569	114850	79835	Row 35 x outmigrant survival through Delta
38	SMOLTS TRUCKED TO CHIPPS ISLAND	3614277	3087139	2560000	2560000	2907911	(Row 34 + Row 25) x survival of smolts released in Delta
39	TOTAL SMOLTS TO CHIPPS ISLAND	3614277	3156523	2671569	2674850	2987746	Row 36 + Row 37
40	YEARLINGS TO CHIPPS ISLAND	360000	360000	360000	360000	360000	Row 26 x survival of yearlings released at MRFH + Row 27 x survival of yearlings released in Delta
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	130028	116296	101747	101846	111232	Row 38 x ocean survival for smolts + Row 39 x ocean survival for yearlings
42	NUMBER HARVESTED	85819	76755	67153	67218	73413	Row 40 x (1 - percent surviving harvest)
43	TOTAL NUMBER LEFT TO SPAWN	44210	39541	34594	34627	37819	Row 40 x percent surviving harvest
44	NUMBER STRAYING TO OTHER RIVERS	36124	31122	26079	26084	29401	(Row 36 x Row 14 x Row 16 x Row 17)+(Row 37 x Row 14 x Row 16 x Row 18)+ (Row 26 x Row 13 x Row 15 x Row 16 x Row 17) + (Row 27 x Row 12 x Row 15 x Row 16 x Row 18)
45	NUMBER RETURNING TO MOKELUMNE	8086	8418	8515	8544	8418	Row 42 - Row 43

Table E.4. Life cycle model output (cont.).

PRODUCTION ORIENTED ALTERNATIVE, HATCHERY EMPHASIS

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	46%	18%	18%	18%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	40%	51%	54%	54%
8	OUTMIGRANTS TRAPPED AND TRUCKED	100%	0%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	24%	44%	44%	44%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	EXPLANATION
19	INITIAL TOTAL NUMBER OF SPAWNERS	5000	5000	5000	5000	5000	Initial size of spawning run
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	1150	1150	1150	1150	1150	Initial total number of spawners x 23%
21	EGGS FROM FISH RETURNING TO HATCHERY	1851500	1851500	1851500	1851500	1851500	number spawning in hatchery x % females x eggs per female
22	TOTAL HATCHERY EGGS NEEDED	6851500	6851500	6851500	6851500	6851500	1.25 x number of smolts and yearlings
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	5000000	5000000	5000000	5000000	5000000	total hatchery eggs needed - eggs from fish returning
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	310900	310900	310900	167886	determined by management plan
25	NUMBER OF SMOLTS RELEASED IN DELTA	3310900	3000000	3000000	3000000	3143014	determined by management plan
26	NUMBER OF YEARLINGS RELEASED AT MRFH	800000	800000	800000	800000	800000	determined by management plan
27	NUMBER OF YEARLINGS RELEASED IN DELTA	0	0	0	0	0	determined by management plan
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	3850	3850	3850	3850	3850	Initial total number of spawners - number spawning in hatchery
29	EGGS DEPOSITED IN RIVER	6198500	6198500	6198500	6198500	6198500	number spawning naturally x % female x eggs per female
30	FRY HATCHING IN RIVER	1549625	1549625	1549625	1549625	1549625	Row 29 x egg to fry survival
31	NATURAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	Row 30 x fry to smolt survival x outmigrant survival to L. Lodi
32	TOTAL SMOLTS ENTERING LAKE LODI	1006946	1302301	1302301	1302301	1166438	Row 31 + (smolts released at MRFH x outmigrant survival to L. Lodi)
33	SMOLTS SURVIVING LAKE LODI	402779	664174	703243	703243	557997	Row 32 x survival through L. Lodi
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	402779	0	0	0	185278	Row 33 x % trapped and trucked
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	292236	309427	309427	163996	(Row 33 - Row 34) x outmigrant survival from Woodbridge to Delta
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	225959	239250	239250	126803	(Row 33 - Row 34 - surviving hatchery plants) x outmigrant survival from Woodbridge to Delta
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	43835	46414	46414	24599	Row 35 x outmigrant survival through Delta
38	SMOLTS TRUCKED TO CHIPPS ISLAND	2970943	2400000	2400000	2400000	2662634	(Row 34 + Row 25) x survival of smolts released in Delta
39	TOTAL SMOLTS TO CHIPPS ISLAND	2970943	2443835	2446414	2446414	2687233	Row 36 + Row 37
40	YEARLINGS TO CHIPPS ISLAND	360000	360000	360000	360000	360000	Row 26 x survival of yearlings released at MRFH + Row 27 x survival of yearlings released in Delta
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	110728	94915	94992	94992	102217	Row 38 x ocean survival for smolts + Row 39 x ocean survival for yearlings
42	NUMBER HARVESTED	73081	62644	62695	62695	67463	Row 40 x (1 - percent surviving harvest)
43	TOTAL NUMBER LEFT TO SPAWN	37648	32271	32297	32297	34754	Row 40 x percent surviving harvest
44	NUMBER STRAYING TO OTHER RIVERS	29890	24425	24429	24429	26940	(Row 36 x Row 14 x Row 16 x Row 17)+(Row 37 x Row 14 x Row 16 x Row 18)+ (Row 26 x Row 13 x Row 15 x Row 16 x Row 17) + (Row 27 x Row 12 x Row 15 x Row 16 x Row 18)
45	NUMBER RETURNING TO MOKELUMNE	7758	7846	7869	7869	7814	Row 42 - Row 43

Table E.4. Life cycle model output (cont.).

MAXIMUM HARVEST ALTERNATIVE

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	16%	34%	36%	14%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	32%	29%	28%	28%
8	OUTMIGRANTS TRAPPED AND TRUCKED	100%	100%	100%	100%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	20%	20%	37%	37%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	EXPLANATION
19	INITIAL TOTAL NUMBER OF SPAWNERS	5000	5000	5000	5000	5000	Initial size of spawning run
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	1150	1150	1150	1150	1150	Initial total number of spawners x 23%
21	EGGS FROM FISH RETURNING TO HATCHERY	1851500	1851500	1851500	1851500	1851500	number spawning in hatchery x % females x eggs per female
22	TOTAL HATCHERY EGGS NEEDED	5833000	5833000	5833000	5833000	5833000	1.25 x number of smolts and yearlings
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	3981500	3981500	3981500	3981500	3981500	total hatchery eggs needed - eggs from fish returning
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	0	0	0	0	determined by management plan
25	NUMBER OF SMOLTS RELEASED IN DELTA	0	0	0	0	0	determined by management plan
26	NUMBER OF YEARLINGS RELEASED AT MRFH	0	0	0	0	0	determined by management plan
27	NUMBER OF YEARLINGS RELEASED IN DELTA	3499800	3499800	3499800	3499800	3499800	determined by management plan
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	3850	3850	3850	3850	3850	Initial total number of spawners - number spawning in hatchery
29	EGGS DEPOSITED IN RIVER	6198500	6198500	6198500	6198500	6198500	number spawning naturally x % female x eggs per female
30	FRY HATCHING IN RIVER	1549625	1549625	1549625	1549625	1549625	Row 29 x egg to fry survival
31	NATURAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	Row 30 x fry to smolt survival x outmigrant survival to L. Lodi
32	TOTAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	Row 31 + (smolts released at MRFH x outmigrant survival to L. Lodi)
33	SMOLTS SURVIVING LAKE LODI	322223	292014	281945	281945	291813	Row 32 x survival through L. Lodi
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	322223	292014	281945	281945	291813	Row 33 x % trapped and trucked
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	0	0	0	0	(Row 33 - Row 34) x outmigrant survival from Woodbridge to Delta
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	0	0	0	0	(Row 33 - Row 34 - surviving hatchery plants) x outmigrant survival from Woodbridge to Delta
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	0	0	0	0	Row 35 x outmigrant survival through Delta
38	SMOLTS TRUCKED TO CHIPPS ISLAND	257778	233612	225556	225556	233450	(Row 34 + Row 25) x survival of smolts released in Delta
39	TOTAL SMOLTS TO CHIPPS ISLAND	257778	233612	225556	225556	233450	Row 36 + Row 37
40	YEARLINGS TO CHIPPS ISLAND	3149820	3149820	3149820	3149820	3149820	Row 26 x survival of yearlings released at MRFH + Row 27 x survival of yearlings released in Delta
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	196723	195998	195756	195756	195993	Row 38 x ocean survival for smolts + Row 39 x ocean survival for yearlings
42	NUMBER HARVESTED	129837	129358	129199	129199	129355	Row 40 x (1 - percent surviving harvest)
43	TOTAL NUMBER LEFT TO SPAWN	66886	66639	66557	66557	66638	Row 40 x percent surviving harvest
44	NUMBER STRAYING TO OTHER RIVERS	63541	63307	63229	63229	63306	(Row 36 x Row 14 x Row 16 x Row 17) + (Row 37 x Row 14 x Row 16 x Row 18) + (Row 26 x Row 13 x Row 15 x Row 16 x Row 17) + (Row 27 x Row 12 x Row 15 x Row 16 x Row 18)
45	NUMBER RETURNING TO MOKELUMNE	3344	3332	3328	3328	3332	Row 42 - Row 43

Table E.4. Life cycle model output (cont.).

CDFG 1991 AGREEMENT

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	0%	14%	47%	39%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	30%	32%	72%	74%
8	OUTMIGRANTS TRAPPED AND TRUCKED	0%	100%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	50%	50%	95%	95%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	EXPLANATION
19	INITIAL TOTAL NUMBER OF SPAWNERS	0	5000	5000	5000	5000	Initial size of spawning run
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	0	1150	1150	1150	1150	Initial total number of spawners x 23%
21	EGGS FROM FISH RETURNING TO HATCHERY	0	1851500	1851500	1851500	1851500	number spawning in hatchery x % females x eggs per female
22	TOTAL HATCHERY EGGS NEEDED	0	2301250	2488750	2488750	2463015	1.25 x number of smolts and yearlings
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	0	449750	637250	637250	611515	total hatchery eggs needed - eggs from fish returning
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	0	150000	150000	129412	determined by management plan
25	NUMBER OF SMOLTS RELEASED IN DELTA	0	1370000	1370000	1370000	1370000	determined by management plan
26	NUMBER OF YEARLINGS RELEASED AT MRFH	0	56000	56000	56000	56000	determined by management plan
27	NUMBER OF YEARLINGS RELEASED IN DELTA	0	415000	415000	415000	415000	determined by management plan
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	0	3850	3850	3850	3850	Initial total number of spawners - number spawning in hatchery
29	EGGS DEPOSITED IN RIVER	0	6198500	6198500	6198500	6198500	number spawning naturally x % female x eggs per female
30	FRY HATCHING IN RIVER	0	1549625	1549625	1549625	1549625	Row 29 x egg to fry survival
31	NATURAL SMOLTS ENTERING LAKE LODI	0	1006946	1006946	1006946	1006946	Row 30 x fry to smolt survival x outmigrant survival to L. Lodi
32	TOTAL SMOLTS ENTERING LAKE LODI	0	1006946	1149446	1149446	1129888	Row 31 + (smolts released at MRFH x outmigrant survival to L. Lodi)
33	SMOLTS SURVIVING LAKE LODI	0	322223	827601	850590	767251	Row 32 x survival through L. Lodi
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	0	322223	0	0	44227	Row 33 x % trapped and trucked
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	0	786221	808061	686873	(Row 33 - Row 34) x outmigrant survival from Woodbridge to Delta
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	0	117933	121209	103031	(Row 33 - Row 34 - surviving hatchery plants) x outmigrant survival from Woodbridge to Delta
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	1353778	1096000	1096000	1131381	Row 35 x outmigrant survival through Delta
38	SMOLTS TRUCKED TO CHIPPS ISLAND	0	1353778	1213933	1217209	1234412	(Row 34 + Row 25) x survival of smolts released in Delta
39	TOTAL SMOLTS TO CHIPPS ISLAND	0	398700	398700	398700	398700	Row 36 + Row 37
40	YEARLINGS TO CHIPPS ISLAND	0	64535	60340	60438	60954	Row 26 x survival of yearlings released at MRFH + Row 27 x survival of yearlings released in Delta
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	0	42593	39824	39889	40230	Row 38 x ocean survival for smolts + Row 39 x ocean survival for yearlings
42	NUMBER HARVESTED	0	21942	20516	20549	20724	Row 40 x (1 - percent surviving harvest)
43	TOTAL NUMBER LEFT TO SPAWN	0	20434	18116	18121	18436	Row 40 x percent surviving harvest
44	NUMBER STRAYING TO OTHER RIVERS	0	1508	2399	2428	2288	(Row 36 x Row 14 x Row 16 x Row 17) + (Row 37 x Row 14 x Row 16 x Row 18) + (Row 26 x Row 13 x Row 15 x Row 16 x Row 17) + (Row 27 x Row 12 x Row 15 x Row 16 x Row 18)

Table E.4. Life cycle model output (cont.).

CDFG 1961 AGREEMENT

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	0%	14%	47%	39%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	0%	33%	29%	30%
8	OUTMIGRANTS TRAPPED AND TRUCKED	0%	100%	100%	100%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	0%	24%	44%	44%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	EXPLANATION
19	INITIAL TOTAL NUMBER OF SPAWNERS	0	5000	5000	5000	5000	Initial size of spawning run
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	0	1150	1150	1150	1150	*Initial total number of spawners* x 23%
21	EGGS FROM FISH RETURNING TO HATCHERY	0	1851500	1851500	1851500	1851500	number spawning in hatchery x % females x eggs per female
22	TOTAL HATCHERY EGGS NEEDED	0	3166667	3166667	3166667	3166667	1.25 x number of smolts and yearlings
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	0	1315167	1315167	1315167	1315167	total hatchery eggs needed - eggs from fish returning
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	0	0	0	0	determined by management plan
25	NUMBER OF SMOLTS RELEASED IN DELTA	0	1370000	1370000	1370000	1370000	determined by management plan
26	NUMBER OF YEARLINGS RELEASED AT MRFH	0	0	0	0	0	determined by management plan
27	NUMBER OF YEARLINGS RELEASED IN DELTA	0	530000	530000	530000	530000	determined by management plan
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	0	3850	3850	3850	3850	Initial total number of spawners - number spawning in hatchery
29	EGGS DEPOSITED IN RIVER	0	6198500	6198500	6198500	6198500	*number spawning naturally* x *% female* x *eggs per female*
30	FRY HATCHING IN RIVER	0	1549625	1549625	1549625	1549625	Row 29 x egg to fry survival
31	NATURAL SMOLTS ENTERING LAKE LODI	0	1006946	1006946	1006946	1006946	Row 30 x fry to smolt survival x outmigrant survival to L. Lodi
32	TOTAL SMOLTS ENTERING LAKE LODI	0	1006946	1006946	1006946	1006946	Row 31 + (smolts released at MRFH x outmigrant survival to L. Lodi)
33	SMOLTS SURVIVING LAKE LODI	0	332292	292014	302084	301492	Row 32 x survival through L. Lodi
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	0	332292	292014	302084	301492	Row 33 x % trapped and trucked
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	0	0	0	0	(Row 33 - Row 34) x outmigrant survival from Woodbridge to Delta
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	0	0	0	0	(Row 33 - Row 34 - surviving hatchery plants) x outmigrant survival from Woodbridge to Delta
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	0	0	0	0	Row 35 x outmigrant survival through Delta
38	SMOLTS TRUCKED TO CHIPPS ISLAND	0	1361834	1329612	1337667	1337193	(Row 34 + Row 25) x survival of smolts released in Delta
39	TOTAL SMOLTS TO CHIPPS ISLAND	0	1361834	1329612	1337667	1337193	Row 36 + Row 37
40	YEARLINGS TO CHIPPS ISLAND	0	477000	477000	477000	477000	Row 26 x survival of yearlings released at MRFH + Row 27 x survival of yearlings released in Delta
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	0	69475	68508	68750	68736	Row 38 x ocean survival for smolts + Row 39 x ocean survival for yearlings
42	NUMBER HARVESTED	0	45854	45216	45375	45366	Row 40 x (1 - percent surviving harvest)
43	TOTAL NUMBER LEFT TO SPAWN	0	23622	23293	23375	23370	Row 40 x percent surviving harvest
44	NUMBER STRAYING TO OTHER RIVERS	0	22440	22128	22206	22202	(Row 36 x Row 14 x Row 16 x Row 17) + (Row 37 x Row 14 x Row 16 x Row 18) + (Row 26 x Row 13 x Row 15 x Row 16 x Row 17) + (Row 27 x Row 12 x Row 15 x Row 16 x Row 18)
45	NUMBER RETURNING TO MOKELUMNE	0	1181	1165	1169	1169	Row 42 - Row 43

Table E.5. Fishery benefits of management alternatives

MANAGEMENT ALTERNATIVE	CHINOOK SALMON PREDICTED FISHERY BENEFITS						
	INITIAL RUN SIZE	TOTAL SMOLT PRODUCTION (1)	TOTAL YEARLING PRODUCTION (1)	NATURAL SMOLTS (2)	HARVEST	SYSTEM ESCAPEMENT (3)	MOKELUMNE RETURNS
CDFG ALTERNATIVE	5,000	1,685,192	675,000	567,948	60,097	30,959	13,259
ESCAPEMENT ALTERNATIVE	5,000	1,252,030	477,000	339,366	43,679	22,502	1,540
PRODUCTION, NATURAL EMPHASIS	5,000	2,987,746	360,000	430,571	73,413	37,819	8,418
PRODUCTION, HATCHERY EMPHASIS	5,000	2,687,233	360,000	126,803	67,463	34,754	7,814
MAXIMUM HARVEST	5,000	233,450	3,149,820	0	129,355	66,638	3,332
BASE CASE, 1961 DFG AGREEMENT	5,000	1,337,193	477,000	0	45,366	23,370	1,169
EXISTING FLOW CONDITION	5,000	1,222,386	477,000	584,582	43,092	22,199	1,825

(1) Total Smolt and Yearling Production measured at Chipps Island

(2) Natural Smolt Production measured at mouth of the Mokelumne (near Thornton)

(3) System Escapement includes returns to all Central Valley streams and hatcheries (Sacramento and San Joaquin watersheds).